



(17)

## DALTONISM.

May. 1880

THIS is the name given, in many parts of Europe, to a curious defect in the vision of colours, which was first prominently brought into notice by the immortal discoverer of the Atomic Theory, in a description written by him of his own case. English authors use in preference the term "Colour-blindness;" asserting that the continental designation is disrespectful to a great man; but there appears reason to believe that the word was used in Dalton's lifetime, and gave no offence to him. Indeed he was more amused than annoyed by his singularity of vision, and was always ready to satisfy the curiosity of others in reference to it. I use the personal name here, as I shall have much to say about the phenomena of Dalton's vision. The subject has lately been attracting much notice; it is a matter of curiosity to the public, and of physiological interest to scientific men; and moreover it has some practical bearings. It is, however, still imperfectly understood, and many points connected with it are open to controversy. I propose, as a humble successor of Dalton in the experience of the defect, to give some account of the most modern state of knowledge in regard thereto.

The perception of colour would seem, according to the ideas of those who have not studied the subject, to be as positive and unmistakable as the perception of form. Take, for example, a square red flag: the world in general will consider the *redness* of the flag to be a quality about which there can be as little mistake as its squareness, and they can no more understand how anyone can see it as green or yellow, than how he can see it as round or triangular. I have often amused myself by watching the odd impression produced on intelligent shop-assistants who have to do with colours, by a mention of some of the peculiarities of colour-blindness. Taking up, say, two ribbons of

peculiar shades of red and green, or green and gray, I have asked whether they could conceive it possible that the two appeared to me the same colour? Such a question is usually received with a blank stare of amazement at what is thought to be a foolish joke, and if I attempt explanation, it is seldom they can be brought to believe I am really serious in the assertions made. And it must be admitted that the recorded instances of mistakes can be scarcely credible to those who are new to the subject. A naval officer purchases red breeches to match his blue uniform;—a tailor repairs a black article of dress with crimson cloth;—a painter colours trees red, the sky pink, and human cheeks blue;—a clerk writes a letter half in black and half in red ink without noticing the difference;—and so on. Abundance of such instances could be cited which must indeed appear astounding to the normal-eyed, and Goethe only expresses a very common sentiment when he says—"The remarks made by colour-blind persons as to objects about them are so perplexing as almost to lead one to doubt one's own sanity."\* This feeling is a very natural one, for there is no *primâ facie* reason to expect that light-rays of a certain wave-length should affect the eyes of two healthy individuals in ways so entirely different as to lead, in one of them, to a total subversion of the established ideas. However, such is the fact, and we have to accept it as a biological phenomenon deserving of careful investigation.

It is necessary to premise that considerable varieties are believed to exist in the intensities of the colour-sensations among those who may be correctly described as normal-eyed: persons may differ in their appreciation of colours, and in their judgment upon them, without manifesting any glaring departure from the ordinary views. These cases do not come within the category of true colour-blindness, which refers exclusively to a colour-vision altogether different from that of mankind in general, and in which many of the ordinary sensations of colour are totally wanting. This will clearly be seen when its characteristics come to be explained.

Although the defect has only recently become known, it has probably been co-existent with vision itself. A theory has been started that the sense of colour has been going through a course of gradual development within historical times, and the attempt of Mr. Gladstone to prove, from the writings of Homer, that in his day this sense was generally in an imperfect condition, is fresh in our recollection. It is certainly a singular fact that the expressions for colour used by Homer correspond almost identically with those that a colour-blind person might be expected to employ,† and the antiquity of the affection may be further inferred from its hereditary character. But it would be out of place

\* "Wenn man die Unterhaltung mit ihnen dem Zufall überlässt, und sie bloss über vorliegende Gegenstände befragt, so geräth man in die grösste Verwirrung und fürchtet wahnsinnig zu werden."—*Zur Farbenlehre*.

† See *Nature*, for October, 1878.

here to go into abstruse historical speculations; it is certain that the cases which have existed have generally escaped notice. It was only when the progress of modern science had begun to stimulate the observation of natural phenomena that they made themselves known. The first discovery of abnormal colour vision appears to have been made, in the middle of the last century, by a humble shoemaker, named Harris, living at Maryport, in Cumberland. Having by accident, when four years old, found in the street a child's stocking, he carried it to a neighbouring house to inquire for the owner; he noticed that the people called it a *red* stocking, though he did not understand why they gave it that denomination, as he himself thought it completely described by being called a *stocking*. The circumstance set him a-thinking, and in after-life, being an intelligent man, he determined to make himself acquainted with the nature of light and colour, for which purpose he attended a course of lectures on Natural Philosophy. Subsequent observations then led him to the conclusion that his vision was defective. His case came to the knowledge of a gentleman named Huddart, residing in the neighbourhood, who, after several interviews with him, wrote an account of it to Dr. Priestley. The facts were thought of sufficient novelty to be laid before the Royal Society, and the letter was read at their meeting on February 13, 1787, and was published in the Philosophical Transactions for that year. The actual data of the case are but scanty, for poor Harris had died suddenly before Mr. Huddart wrote his letter. His chief evidence was that he found other persons named colours with confidence and precision, which he could only guess at with hesitation and frequently with error; he confounded different colours together, and mentioned in particular that he could not distinguish cherries on a tree from the leaves, except by their shape. Meagre as the details are, they are sufficient, by the light of subsequent knowledge, to identify the defect. Harris had, moreover, a brother, whose vision he found also abnormal, and Mr. Huddart mentions, in regard to him, a symptom now well known, that of confounding red or yellow with green.

The case of Mr. Harris excited only a temporary curiosity, and the subject had probably been forgotten, when it was revived by the publication of the memorable paper by Dalton, in 1794; and it is to this paper, and to the investigations subsequently founded on it, that I have here principally to direct attention.

John Dalton was born in 1766; from 1781 to 1793 he was engaged, first as assistant and afterwards as principal, in a boarding-school at Kendal, and during this time he employed his leisure in the study of literature and science, a study leading eventually to the brilliant results that have given lustre to his name. In the course of his application to the sciences, that of optics necessarily claimed attention, and he became, he says, pretty well acquainted with the theory of light and colours long before he was aware of any peculiarity in his vision. He



had, however, an impression that there was some perplexity in colour nomenclature. He always held an opinion, though he did not often care to mention it, that several colours were injudiciously named. He thought, for example, that to use the term red as having any analogy with pink was highly improper, as the two appeared to him to have scarcely any relation; in his apprehension, pink was much more nearly allied to blue.

After the year 1790, he took up the occasional study of botany, which obliged him to attend more to colour than before. He still found the same apparent inconsistencies, and often seriously asked questions of his friends which they considered as only put in jest. But he was never convinced of a peculiarity in his vision till the year 1792, when an accidental observation made on a geranium flower, and a comparison of his impression of its colour with those of some of his friends, led to the discovery. Two years afterwards he entered on an investigation of the subject, the result of which was the presentation to the Literary and Philosophical Society of Manchester of the paper above mentioned. It was the first scientific communication he ever published; it was read before the Society on 31 October, 1794, and was printed in vol. v. of their Transactions.

The title is "Extraordinary Facts relating to the Vision of Colours, with Observations. By Mr. John Dalton." He appears to have been struck by the singularity of the fact that differences in colour-vision could have existed, in his own and other cases, for a long time without becoming known. He says at the outset:—

"It will scarcely be supposed that any two objects, which are every day before us, should appear hardly distinguishable to one person, and very different to another, without the circumstance immediately suggesting a difference in their faculties of vision; yet such is the fact, not only with regard to myself, but to many others also."

This fact, however, is amply corroborated by subsequent experience, true cases of the defect being always difficult to find and to establish, though known to exist in large numbers.

Dalton goes on in his paper to give an account of his own vision. He began his observations with the solar spectrum, in which he says he saw only two, or at most three, distinctions, which he called yellow and blue, or yellow, blue, and purple, the part called red appearing to him little more than a shade, or defect of light. He then speaks of the colours of bodies in general, taking them in the spectral order. With regard to the different kinds of *red*, he describes all crimsons as resembling dirty blue or brown; pink as light or sky blue, a little faded; the colour of a florid complexion he compares to diluted black ink, or dusky blue. Scarlet, such as vermilion or a soldier's coat, he describes as giving a totally different impression, which he appears to have recognized as a distinct sensation, giving it accordingly the name of red. In *orange* and *yellow* he did not find that he differed materially from other people. In *green*, however, anomalies again arose; grass is described as little different

from red, a laurel-leaf making a good match with a stick of red sealing-wax. Brown appeared to him green, and very light green did not differ from white. Dark green woollen cloth seemed a muddy red, much darker than grass, and of a very different colour. *Blue*, he thinks, appeared the same to him as to other people; and *violet*, or purple, was a slight modification of it, which however he could hardly suspect to be a compound of blue and red.

In looking over this account, it is difficult to draw from it any clear and simple explanation of what Dalton's sensations of colour really were. There are evidently the most glaring discrepancies with normal vision; but, as he appears to imply that he had really sensations corresponding, not only to yellow and blue, but also to red, orange, green, and violet, the way in which these discrepancies arose appears incomprehensible.

At a later time, however, the difficulty was solved. Sir John Herschel, who had, as is well known, made extensive and profound researches on light and colour, became acquainted with Dalton's peculiarity, and determined to investigate it more thoroughly. For this purpose he sent him a large number of skeins of silk, of a great variety of colours, and asked him to match such as appeared to him alike, and generally to express his opinion as to their appearance. Dalton did this with great care, and returned the samples; and I am fortunately able to make public, for the first time, the interesting data thus obtained. About twenty years after Dalton's death, Sir John Herschel, in the course of an investigation into the nature of my own vision, lent me the samples, with Dalton's notes upon them, and asked me to compare the latter with my own impressions. There can be now no objection to the publication of the data, which are contained in the following table.

The first column gives the actual colours of the samples, as carefully named by normal-eyed persons, and the second column contains Dalton's notes upon them. The third column is my own description, which I shall explain hereafter.

*Description, by JOHN DALTON, of the appearance to him of a number of samples of coloured silk.*

Normal description of the Colours.	Dalton's description.	Description by another Colour-blind person.
<i>I. Single samples.</i>		
Crimson . . .	Reddish brown	} Yellow, 18
Brown . . .	Yellowish brown	
Red violet . . .	Red and blue; latter prevails	} Gray, 16
Gray . . .	Slate blue, brighter than the foregoing sample, but nearly allied to it	
Blue black . . .	Blue black	} Gray, 13
Black, pure . . .	Brown black	
Yellow orange	Yellow, or light orange	
Yellow . . .	Yellow	
		Blue, 20
		Black, no colour
		Yellow, 13, but more colour
		Yellow, 10

Normal description of the Colours.	Dalton's description.	Description by another Colour- blind person.
Yellow, intense	Yellow	Yellow, 10, but more colour
Lilae . . .	Blue, or lilae	Blue, 5
Pink . . .	Faint blue, tinge of yellow	Gray, 6
Pink . . .	Blue	Gray, 7
Light blue . . {	Blue, but not so bright a colour as the last	{ Blue, 5, dirty or dark
Brown . . .	Brightish orange hue	Yellow, 16
Brown . . . {	Light red, orangey brown, snuff colour	{ Yellow, 16, or 17
Red . . .	Brown	Yellow, 17, but less colour
Brown . . .	Red brown	Yellow, 17, or 18
II. <i>Samples matched together.</i>		
Orange . . . {	Orange } Alike, and nearly the	{ Yellow, 14
Yellow green . {	yellow } colour of gold	
Yellowish pink (salmon) {	Alike on first glance, but there is a shade of differencee	{ Yellow, 13, with less colour
Yellow green . {		{ Yellow, 16
Green . . . {	Brown and nearly alike, first	{ Yellow, 19 $\frac{1}{2}$
Red . . . {	rather brighter than second	{ Yellow, 17
Brown . . . {	and third	{ Yellow, 19
Blue, pure . . {	Dark blue, nearly alike, first	{ Blue, 13, or 14, but colour
Violet . . . {	rather more vivid	{ more intense
Green . . . {	Alike, and may be called orange,	{ Yellow, 17, but less colour
Red orange . {	green, or brown	{ Yellow, 16
Lilae . . . {		
Blue gray . . {	All blue, with slight shades of	{ Blue, 5, or 6, some rather
Lavender . . {	differencee, the last has a faint	{ dirty
Light blue . . {	tinge of red	{ Gray, 8
Pink . . . {		
Red orange . {		
Brown . . . {	All alike, an orangey red colour	{ Yellow, 14, 15, or 16, with
Orange brown {	with slight shades of differencee	{ variations of intensity of
Light red . . {		{ colour
Red . . . {	Red brown, very good matches	Yellow, 15 to 18
Brown . . . {		
Red . . . {	These nearly match	{ Yellow, 16
Green . . . {		{ Yellow, 18
Green . . . {	May all be classed among brown	Yellow, 18
Brown . . . {		
Brown . . . {	All darkish browns, with scarcely	{ Yellow, 19 or 20
Several varieties of green . . }	a shade of differencee	

The list is divided, for convenience of reference, into two parts: in the first, Dalton has simply described, in his own words, the appearance to him of isolated samples; in the second part he has selected several pairs and small sets of samples, which to his eye *matched*, or nearly matched, each other; and has given a common description for each set.



The latter is the most interesting and instructive, as the matching shows the nature of the vision independently of nomenclature, which is not always to be depended on. The phenomena here are unmistakable, as he matches red with green, pink with green, orange with green, green with brown, blue with violet, lilac with gray, blue with pink, and red with orange;—mistakes which I suppose must appear to ordinary people of the most astounding character, and indicating a kind of vision which to them must be altogether incomprehensible.

To Sir John Herschel's practised judgment, however, the evidence gained by these tests furnished all the data he wanted; for, by applying to them his great scientific knowledge of the subject of colour, he succeeded in solving the problem of Dalton's vision, and in dispelling the confusion in which it appeared to be involved. He communicated his discovery to Dalton himself, in a letter dated May 20, 1833, which was printed in Henry's "Life of Dalton" in 1856. The important part the letter is as follows:—

"Your replies to my optical queries agree, on the whole, with the views I had taken of this singular affection of vision, and seem to throw much light on the matter.

"The question is reduced to one of pure sensation. It seems to me that we have three primary sensations when *you have only two*. We refer, or can refer in imagination, all colours to three, red, yellow, blue.\* All other colours we think we perceive to be mixtures of these.

"Now to eyes of your kind it seems to me that all your tints are referable to two, which I shall call A and B, the equilibrium of A and B producing your white, their negation your black, and their mixture in various proportions your compound tints. With regard to what sort of sensations A and B are, of course we can no more tell than you can tell what our  $\alpha$ ,  $\beta$ , and  $\gamma$  (red, yellow, and blue) are.

"Only this appears to be demonstrated by all the cross-examinations I have ever been able to give any persons so affected with what I think, after all, may be termed 'Dichromic Vision';—as well as by your answers to my queries;—viz., that the same rays which excite in us the sensation  $\gamma$  (blue) excite in you the sensation B; and those rays which excite in us the two distinct sensations,  $\alpha$  and  $\beta$ , excite in you only the one sensation A."

I may now take up my own ease, which forms an appropriate sequel to that of Dalton.† I believe I was about eight or ten years old when the mistaking of a piece of red cloth for a green leaf betrayed the existence of some peculiarity in my ideas of colour; and as I grew older, continued errors of a similar nature led my friends to suspect that my eyesight was defective; but I myself could not comprehend this, insisting that I saw colours clearly enough; and only mistook their names. In my subsequent occupations I had much to do with drawings, and I recollect often being obliged to ask, in the process of colouring, what colour I ought to use; but these difficulties left no

\* Sir John afterwards modified his views as to the nature of the primary sensations, in accordance with the results of later discoveries.

† I do not scruple to make extracts from my former writings on the subject, where I think they will be appropriate.

permanent impression, and up to a mature age I had no suspicion that my vision was different from that of other people. I frequently made mistakes, and noticed, as Dalton did, many circumstances in regard to colours which temporarily perplexed me; for example, I often wondered why the beautiful rose light of sunset on the Alps, which threw my friends into raptures, seemed all a delusion to me. But I still adhered to my first opinion, that I was only at fault with regard to the names of colours, and not as to the ideas of them, and this opinion was strengthened by observing that the persons who pointed out my mistakes often disputed among themselves as to what certain hues of colour ought to be called.

I was nearly thirty years of age (here corresponding again with Dalton) when a glaring blunder, persisted in by me in opposition to the positive evidence of others, led me seriously to suspect that my vision of colours must be defective, and this suspicion once admitted, it was soon confirmed by further observations. I became acquainted with the records of similar cases, and gradually acquired information on the subject, which guided me in the examination of my own symptoms. I cannot now recollect the process of investigation that I followed, but when I became aware of Sir John Herschel's masterly suggestion of Dichromic Vision, all difficulty was removed, and the nature of my case became perfectly intelligible. At that time some doubts had been expressed, by good authorities, whether the dichromic hypothesis was sufficient to explain all the varied and anomalous symptoms which had been described, and the difficulty had been urged specially in Dalton's case. But it was clear to me that the objection was groundless, and in this belief I wrote a paper for the Royal Society, in which I explained in full detail the nature of my own colour sensations, comparing them with the accounts of other cases. I endeavoured to show in the first place, that notwithstanding the apparent variety of the symptoms in different persons, the defect was uniform, or nearly so, in all;—and secondly, that in spite of the apparent complexity of the phenomena, they might all be explained on the very simple hypothesis of dichromic vision. My paper was published in the "Philosophical Transactions" (vol. exlix. p. 323), and it drew from Sir John Herschel, to whom it was referred, an Essay so valuable, that, contrary to the usual rule, this was also published ("Proc. R. S." for 1859). I believe the explanations I gave have been generally accepted, and subsequent experience has amply confirmed them.

The dichromic theory renders it easy to state what the sensations of colour-blindness are, although it is not so easy for a normal-eyed person to imagine the appearances and impressions, so utterly strange to him, which they lead to. The colour-blind person has only two sensations of colour. One of them is excited most strongly by rays which the world call *yellow*; the other by rays which the world call *blue*; and



hence all colour-blind persons concur in giving these names respectively to their two visible colours. But their powers of vision do not end here; they receive a vast number of sensations differing materially from pure yellow and pure blue, and which give great variety to their impressions of material objects. In the first place, they have great varieties in the intensity, or degree of saturation, of the two colours themselves. In some cases the yellow is intense and full, as in the buttercup or the pigment chrome-yellow, at other times it is weak and pale, as in the primrose. And, similarly, in some cases the blue is very full and intense, as in ultramarine, in others weak and pale, as in the colour of the sky.

But further, independently of these two colours, they have a white and a black, as prominent and as distinct to them as to the normal-eyed. Whether the sensations correspond in the two cases is a matter of controversy; but this much is certain—namely, that all objects which convey, to the normal-eyed, *their* sensations of white and black, also convey to the colour-blind person *his* sensations of white and black, for which reason he is perfectly justified in using, for such sensations, the same terms. Further, the colour-blind person is quite capable of appreciating the immense varieties of shade, caused by the mixture of white and black\* in different proportions, forming an almost infinite series of shades of gray. Then, lastly, all these varieties of gray may be combined with the various intensities of either of their two colours, forming different *nuances* of them, and so, still further, vastly increasing the varieties of sensation.

It must be explained that the two colours can never be combined in the same sensation; for in combination they tend to destroy each other, and produce white or gray. Hence, in a mixture of blue and yellow, only that one colour is seen which predominates in the mixture.

Combining these facts, we find that, although, strictly speaking, the Daltonian has only two colour-impressions, yet his sensations of vision give him—

- I. Pure white.
- II. Pure black.
- III. Infinite varieties of gray.
- IV. Yellow in a great variety of intensities.
- V. Combinations of these with the varieties of gray.
- VI. Blue in a great variety of intensities.
- VII. Combinations of these with the varieties of gray.

And as the various aspects of Nature are continually offering changing varieties of these sensations, it is not to be wondered at that colour-blind persons should find a large amount of satisfaction and pleasure in what they see.

But still, when their vision is compared with that of ordinary people, it is undoubtedly of very limited compass. It follows from the above

\* I adopt here, intentionally, Hering's principle of treating black as an independent sensation.

description that, assuming yellow and blue to be the two colours seen, all other colour sensations, such as red, green, orange, violet, and all their combinations, are unknown to the colour-blind. And the question at once arises, what impression on them do these colours make? If red and green are not appreciable, are red and green objects invisible to them? By no means. Everything visible to a normal-eyed person, is visible also to the colour-blind; but objects which to the normal-eye give the sensations of red, green, orange, or violet, give to the colour-blind eye a *false* sensation—namely, one of those included in his visible list. A few examples will make this clear. *Red* is a name given to a great variety of hues; the great majority of these verging towards scarlet present to the colour-blind their sensation No. V., a combination of yellow and gray—*i.e.*, a dark or shaded yellow, or yellow brown; but if the red be a more pink or crimson hue, it may lose the yellow element, and appear simply gray, No. III., or may even convey the sensation No. VII., a dark or shaded blue. *Orange*, in all variations, corresponds with varieties of No. V. *Green* is a very protean and perplexing colour. Yellow greens (which are most predominant in nature) correspond with No. V., neutral greens with No. III., and blue greens with No. VII. *Violet* always simulates No. VII., a dark or shaded blue. *Brown*, of all kinds, finds its representative in No. V.

As a convenient illustration of the above relations, I may now refer to the third column of the Table on pp. 825, 826, which contains the description of how the samples of silk named by Dalton appeared to me. For this description I used three of the colour scales or “*gammes*,” published by M. Chevreul,\* corresponding to yellow, blue, and gray.

The *yellow* scale contains twenty *nuances* formed with the yellow colour and numbered 1 to 20 respectively. No. 10 is full intense yellow, as pure as it can be obtained. Nos. 9 to 1 are various “*tints*” formed by gradually lightening the colour, or reducing the intensity and becoming gradually paler, until, in No. 1, it almost disappears in the whiteness of the paper:—Nos. 11 to 20 are various “*shades*” formed by mixing the pure yellow colour with varying shades of gray, these becoming darker and darker until the yellow almost disappears in the black of No. 20. All these latter may correctly be called “*yellow brown*.” The *blue* scale is formed in the same way with the colour blue. The *gray* scale contains also twenty varieties; No. 1 is white, No. 20 black, and Nos. 2 to 19 are shades of gray passing between them, and gradually darkening as the numbers increase.

Now it will be seen that every colour among the samples is matched to my eye by either some *nuance* of yellow, or some *nuance* of blue, or

\* For a more detailed description of these, see my paper in the “*Phil. Trans.*” They are skilfully and admirably prepared; but I was obliged to point out to Sir John Herschel that they did not completely represent the sensations. Any yellow *nuance* may be denoted by the expression  $Y + W + Bk$  (yellow + white + black), each element of which may be variable. The numbers 1 to 9 in the *gammes* give variations of  $Y$  and  $W$  only;  $Bk$  being omitted; Nos. 11 to 20 give variations of  $W$  and  $Bk$  only,  $Y$  being constant. It is easy, therefore, to imagine values of  $Y + W + Bk$  which are not included in the scale, and I found I wanted such values to match some of the samples as noted in the column. In some cases, too, the colour of the silk was more intense than that on the paper.

some shade of gray. A certain crimson for example appears to me "yellow 18," *i.e.*, a dark yellow brown. A violet appears gray 1 = 6, *i.e.*, a dark gray. A pink is = gray 6—equally colourless, but a lighter gray. An orange and a yellow green appear alike = yellow 14, a yellow slightly shaded. A red and a darker green appear = yellow 16 and 18 respectively, *i.e.*, the same colour, but one a little darker than the other. A certain green and brown appear = yellow 18, or 19, or 20. A blue and a violet appear similar = blue 13 or 14.

A little consideration will show that this explanation easily accounts for the confusing with each other of colours that are entirely distinct to the normal-eyed. We may find a red and a green that both present to the colour-blind the same *nuance* of yellow; or a pink and green that both simulate the same *nuance* of gray, or a green and violet that present the same *nuance* of blue. So that the person confounds the two colours without having the least idea of the proper sensation belonging to either. The colours that he never can confound are yellow and blue, for these are as diametrically opposed to each other in his vision as they are to the normal-eyed.

It will be instructive now to compare my explanation, founded on Sir John Herschel's dichromie theory, with the descriptions given by Dalton, before the idea of this theory was communicated to him. It is difficult, as I have said, to make out from his original paper, how many different colour-sensations he then thought he possessed. *Yellow* and *blue* there is no doubt about, but his expressions as to other colours are indefinite and obscure. As to *red*, he appears to convey the idea that he took it to be a distinct sensation, when it was a scarlet variety. His words are—"My idea of red I obtain from vermilion, minium, a soldier's uniform," &c. The pink and crimson varieties he had clearly no idea of. *Orange* he saw like other persons; but by classing it with yellow he unconsciously throws doubt on the correctness of his assertion. *Green* appeared very little different from red, orange, or brown, which may suffice to prove that if he had the sensation of either of the latter, he cannot have had the sensation of green. His clear and positive statement that in the spectrum "orange, yellow, and green seem one colour," must dispose of the idea of more than one sensation for the three. *Purple* he professes to have seen in the spectrum, but as he adds, it "seemed to him only a slight modification of blue, differing more in degree than in kind," we may consider the independence of this sensation as more than doubtful. *Brown* is mentioned, but this would correspond perfectly with dark yellow. Turning to the later descriptions given to Sir John Herschel, I find he still uses the words red and orange; green he mentions only once, and violet not at all; the great mass of his descriptions refer either to blue, yellow, or brown, the latter meaning only dark yellow.

From the two documents combined it may be fairly gathered that Dalton recognised three distinct colour-sensations—namely, yellow



including brown), blue, and red, meaning by the latter the scarlet variety. The difference between this and my description is the individuality of scarlet, which he appears to have taken to be a distinct sensation from yellow. This is a very common idea among the colour-blind, and as it is one of the chief stumbling-blocks in the way of scientific investigation of the subject, it is necessary to remark on it somewhat fully.

Colour-blind persons must be very liable to associate, almost indissolubly, the true normal name of a colour with the sensation it conveys to their minds. This tendency is enhanced by the fact that it is not an easy matter always to refer different *nuances*—i.e., different tints or shades of any given colour—to the same colour-sensation; so that a modification of *nuance*, if considerable, may easily be supposed to be a different colour. This fact is known to the normal-eyed, and the popular nomenclature of colours furnishes illustrations of it, different *nuances* of the same colour being called by different names. Pink and crimson, lilac and violet, are examples of this; but the most pertinent one to the present case is the well-known and very common term *brown*. This merely means either red + black, or orange + black, or yellow + black; but it always passes popularly as a distinct colour, and the best judges (among whom I may quote Sir John Herschel and Professor Clerk Maxwell) have admitted the great difficulty of acknowledging it to be merely a dark shade of red or orange or yellow.

Now, this being the case, it is highly natural that persons who are continually seeing scarlet under the appearance of yellow-brown, should imagine that the latter sensation (which is certainly very distinct from pure yellow) is what corresponds to the term red, and should speak of it accordingly. My own experience is very decided on this point. It was only after long and careful investigation I came to the conclusion that what I took to be red was merely a modification of one of my other sensations; and if, before I found this out, I had been interrogated on the subject, I should have declared I saw red as a separate colour, just as Dalton did. In the examinations I have made of other patients, I have invariably found the same obstinate clinging to the distinct idea of red, and the same amazement when it was ultimately demonstrated to them that the sensation they called by that name was properly yellow.

A strong argument against the idea that Dalton really saw red is derived from his describing the red end of the spectrum as "little more than a shade or defect of light;" for I may leave any normal-eyed person to judge whether this is consistent with his having had any real sense of the splendid colour exhibited there. Sir John Herschel clearly held the opinion that this was a mistake on Dalton's part, and when I read his descriptions by the light of my own experience, I can fully confirm Sir John's judgment. When this mistake is allowed for, it is clear to me that Dalton's impressions of coloured objects correspond almost identically with my own, and, with very slight alterations, I could use his own language. The only discrepancies amount to nothing more than slight differences of shade; for example, where he says that a

certain red and a certain green match to his eye, I see the latter a little darker than the former, although both are varieties of the same colour, yellow. Differences of this kind are known to be common even in normal eyes. I have, therefore, every reason to believe that Dalton's case corresponds not only with my own, but with all others I have had the opportunity of examining, and that this uniform defect is of the kind correctly named by Sir John Herschel "diehromie vision."

Something may now be said as to the statistics of the disorder. It might at first be supposed that so strange an anomaly could hardly exist to a large extent without making itself observed. Dalton thought so at first, but when he came to inquire among his friends and acquaintances, he found many persons similarly situated. He devotes a separate division of his paper to "An account of others whose vision has been found similar to mine." His own brother was one of these. He also investigated the case of Harris, of Maryport, previously mentioned, and learned there were no less than four of the family with defective vision. He soon found nearly twenty persons so situated, and he took the trouble to satisfy himself as far as possible that the nature of the peculiarity of vision corresponded, in all cases, with his own. Since that time extensive investigations have been made by various enquirers, following a course of systematic testing, and the result is curious. In males, the average is about *four per cent.*, so that one man out of every twenty-five we meet may be fairly guessed to be deficient of any true idea respecting the colours of objects he sees around him. With females the case is very different, the defect in that sex being so rare that women may almost be pronounced free from the liability to it altogether, an interposition of Providence for which they ought to be very grateful. Isolated cases do, however, exist among them. I have one now under examination, of a lady of great intelligence and high culture, and I am pretty sure it will turn out to be as positive and well-defined a case of diehromie vision as my own. It may be added that there is every reason to believe that the defect is hereditary, and this proves its great antiquity.

The physiological nature of colour-blindness is a matter of great interest to scientific men. In investigating this it is very necessary to avoid confounding the true Daltonian defect with any of the milder forms of imperfect vision already referred to. Minor degrees of misapprehension of colour may be due in some cases to want of education in distinguishing complicated hues; or if really physiological defects, they are only so in the *degree* of the sensations, and there is some reason to think that the latter like the former are curable. But the true defect involves a totally different *kind* of visual perception, which is a much more serious matter. It is altogether a delusion to suppose (as many writers in the newspapers lately appear to have done) that this is merely a functional derangement, which has come on at a particular time, or under any particular circumstances, and which may be corrected

by some mode of cure. All sufferers from it agree in testifying that the actual condition of their vision is the only one they have ever known, and is perfectly natural to them; and all investigators agree in the inference that the peculiarity is due to some natural and congenital defect of organic structure or organic action, altogether incapable of cure, or even of amelioration by any known means.

What the exact anatomical or physiological nature of this defect may be, is somewhat obscure. Dalton could not avoid the temptation to exercise his great reasoning power in endeavouring to find this out, and he devoted a third division of his paper to "Observations tending to point out the Cause of our Anomalous Vision." It is a pretty specimen of ingenious reasoning, and he propounds the theory "that one of the humours of my eyes, and of the eyes of my fellows, is a *coloured* medium, probably some modification of blue. I suppose it must be the vitreous humour, otherwise I apprehend it might be discovered by inspection, which has not been done." After Dalton's death, Mr. Ransome, his medical attendant, made, with the consent of the executors, an examination of his eyes, and sacrificed one of them to the determination of the colour of the three humours, which were found, contrary to Dalton's hypothesis, to be in a perfectly normal condition, the vitreous humour and its envelope being perfectly colourless. It was also discovered, by actual testing of the untouched eye, that the rays from objects of different colours passed through it without any appreciable alteration, the contrast being as great as ever. Mr. Ransome and Dr. Brewster (to whom he explained the circumstances at the time) agreed "that the imperfection in vision arose from some deficient sensorial or perceptive power, rather than from any peculiarity in the eye itself."

The explanations given by modern physiologists are all bound up more or less with the theories of light and colour-perception generally; and as these theories, and the explanations founded on them are at present in a very unsettled state, and involve many disputed points, all I will attempt to do here is to give a very brief and general notice of them. According to the most generally received theory, that of Young, the normal visual organs are capable of being impressed with *three colour-sensations*, all colour-perception being caused by the combination of these in varying proportions. The exact nature of the three fundamental sensations is a matter of dispute, but they are generally believed to correspond with some varieties of red, green, and blue or violet. It is assumed that in colour-blind people one of these sensations is wanting, leaving the other two in action, and thus causing dichromic vision. The wanting sensation is supposed to be most commonly either the red or the green; in the former case, which is called red-blindness, the patient is impressible by only green and violet; in the latter, green-blindness, he is impressible by only red and violet. The reason why the colour-blind insist on calling their less refrangible colour yellow, and not red or green, is said to be that the visible sensation, in the absence of a certain alteration normally caused by the missing one, gives its



maximum intensity in a different wave-length from that which affects the normal vision; this wave-length nearly corresponding to the place of yellow in the spectrum. Hence, although the patient receives either a red or a green sensation, yet as he finds it given most powerfully by objects which the normal-eyed call yellow, he calls it yellow also. The same explanation is applied to the more refrangible sensation, which if it is really violet, may thus correspond with blue and be accordingly called so.

A more modern theory, that of Hering,\* assumes *four* fundamental colour-sensations—namely, blue, yellow, red and green. These, however, are said to result from only two *sources* of sensation, each of which is capable of a double, or reversible mode of excitement, producing the sensations of two colours complementary to each other. Thus one of the sources of sensation corresponds to blue and yellow, the blue rays exciting it in one direction, and the yellow rays in the other. The other source corresponds to red and green in like manner. The explanation of colour-blindness on this theory is very simple; normal-eyed persons possess both sources of sensation, colour-blind persons possess only one—namely, that corresponding to blue and yellow, leaving them blind to both red and green, and all their compounds, which is of course dichromic vision.

These conflicting theories are at present under discussion, and it is probable that one of the best means of settling the disputed points may be by the study, more thoroughly and carefully than heretofore, of the visual phenomena manifested by the colour-blind.

There are some practical considerations in regard to colour-blindness which have been much commented on of late; indeed the most modern literature of the subject has been mainly devoted to them. They refer to the competency of colour-blind persons to fill certain social positions where the discrimination of colours is of importance. It is evident that persons having this defect must be at a disadvantage not only in the pictorial arts, but in many scientific, industrial, and commercial occupations. Yet it is remarkable how well they have often contrived to get on, in spite of what normal-eyed judges would predict of their incapacity. Chemists, for example, would say it was impossible for a colour-blind person to meddle with their science, in which colour is one of the most important elements of observation: and yet Dalton somehow made a tolerable name in chemistry. Draughtsmen would ridicule the pretensions of a Daltonian to make, or use, or judge of coloured drawings, and yet I contrived to do all this for years with tolerable success without even knowing that there were any serious difficulties in my way. And if one could get at the facts, I am certain we should find abundance of instances in all sorts of occupations where persons similarly affected, but in happy ignorance of their failing, succeed in blundering through their duties without any serious break-down.

\* See *Nature*, October, 1879.

Such cases as these may be fairly left to the operation of the ordinary laws of business affairs; but the writers on the subject have chiefly busied themselves with one that bears a different character, inasmuch as it directly involves the public safety; this is the possible employment of colour-blind persons on railways and in marine service, where coloured signals are employed. Most people know that red and green lamps are used at railway junctions, the former to stop a train, the latter to allow it to pass on; and at sea the use of red and green lights on the two sides of a vessel, indicates to other ships the way she is going, in order to avoid collisions. Now, as one of the most common symptoms of colour-blindness is the confounding, under certain circumstances, of red with green, it is taken for granted that a colour-blind engine-driver or helmsman must be unable to distinguish between the contradictory signals, and frightful pictures are drawn of the danger that the public are constantly incurring. But what says the inexorable logic of facts? In this country we have not only had a tolerable experience of the working of railways for half a century, but we have gathered a mass of information about railway accidents which is unknown elsewhere. Every casualty that occurs in the three kingdoms is carefully inquired into by a Government Board, and a Report is published as to its causes:—and yet so far as I know, never, in a single instance, since railways have been in use, has an accident been traced to the mistaking of a red for a green night signal. And when we consider that, according to the statistics, about one in every twenty-five engine drivers must have been colour blind, it follows that, if the notions of the alarmists had been true, numbers of collisions would have occurred every day—in fact, that the traffic of the country could not have gone on. The truth is, the agitation has arisen from the difficulty the normal-eyed investigators have in understanding exactly what we, the colour-blind, really see. We could tell them that although the red and green lights do not give us the true red and green sensations, yet still they are strongly contrasted to us, and we are in no danger of mistaking one for the other. The only accident I ever heard of in regard to the colour of a signal was a curious one; a driver when approaching a signal-post, had been looking into a very bright fire, which so affected his vision that for the moment he lost the perception of red; he mistook the red light, not for green, but for *white*, and going at full speed through the wrong points dashed into a train in a siding. On the whole then, I think the alarm on this subject is unnecessarily magnified; but at the same time I do not deny a possibility of danger under certain circumstances, and I would by no means discourage reasonable precautions in the selection of men. The agitation has at least had some good result, for not only has it induced a wide discussion of the phenomena of the defect, but it has given rise to many ingenious and systematic means of discovering its existence, which, previously, was a difficult matter.

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